TENDLER
C E L L U L A R

Robert K Tendler, *Chairman*

DOCKET FILE COPY ORIGINAL
RECEIVED
JUL - 2 2001
FCC MAIL ROOM

June 29, 2001

VIA FEDERAL EXPRESS

Ms. Magalle Roman Salas
Office of the Secretary
Federal Communications Commission
445 12th Street, SW
12th Street Lobby, TW-A325
Washington, D.C. 20554

Re: ET Docket No. 98153 98-153

Dear Ms. Salas:

Enclosed for filing are the comments of Tendler Cellular, Inc. to the NPRM associated with the above mentioned docket.

It would be appreciated if you would forward the original and copies to the appropriate parties.

Sincerely,

Robert K. Tendler

RKT/jmc
Enclosures

No. of Copies rec'd 0+4
List ABCDE

65 Atlantic Avenue, Boston, MA 02110
Telephone 617-720-1339 • Fax 617-723-7186

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Revision of Part 15 of the Commission's	)	ET Docket No. 98-153
Rules Regarding Ultra-Wideband	)	
Transmission Systems	)	

COMMENTS OF TENDLER CELLULAR, INC.

Robert K. Tendler
Chairman
Tendler Cellular, Inc.
65 Atlantic Avenue
Boston, Massachusetts 02110
(617) 720-1339

June 27, 2001

SUMMARY

The authorization of Ultra Wide Band (UWB) constitutes ***intentional jamming*** of GPS, fails to fall under Part 15, and is a threat to public safety causing GPS receivers to ***fail to lock onto GPS satellites*** when employed in ***E-911*** situations to locate injured wireless phone users, thus preventing rescuers from reaching injured parties in time to save lives.

Importantly, UWB authorization would be ***in direct conflict*** with the Report and Order requiring wireless phones to be located by October 1, 2001 because the jamming would affect not only GPS but also the triangulation systems proposed.

Additionally, UWB authorization is ***in contravention*** of International treaties regulating the amount of Radio Frequency Interference acceptable for commercial flight.

Finally, UWB materially affects the operation of military GPS ***(jamming)*** and therefore its authorization is ***a threat to national defense.***

TABLE OF CONTENTS

1. INTRODUCTION

The responder, Tendler Cellular, Inc., is a company which is heavily involved in providing E-911 GPS systems to alert Public Safety Answering Points (PSAPs) as to the location of a stricken individual. Tendler Cellular, Inc. was the first company to successfully integrate a GPS receiver inside a wireless handset, and has since 1995 struggled with the problems of interference with GPS signals from a variety of different sources. Tendler Cellular, Inc. was one of the first responders to the E-911 NPRM which required cellular carriers or manufacturers to locate individuals within 125 meters 67% of the time, and with a demonstration of the wireless phone with a GPS-equipped handset called Fonefinder® to the FCC succeeded in having the FCC issue its Report and Order requiring same (See Docket No. 94-102.)

In terms of public safety, it is paramount that the GPS receiver located in or on the handset be as free from interference as possible. The failure to be able to lock onto the relatively weak GPS satellite signals results in a failure to report position of an incident. This has a disastrous situation since it will be appreciated that the failure to locate an individual with a severed artery can cause the death of the individual due to bleeding. In general, a severed artery can result in the demise of the individual <u>within eight minutes</u>.

II. THE AUTHORIZATION OF ULTRA WIDEBAND (UWB) TRANSMISSION CONSTITUTES INTENTIONAL JAMMING OF GPS AND THEREFORE FAILS TO FALL UNDER PART 15

While it is the understanding of Tendler Cellular, Inc. that the NPRM requiring the revision of Part 15 of the Commission's rules regarding ultra wideband transmission systems has placed the utilization of ultra wideband transmissions within the "unintentional "category, it is the opinion of Tendler Cellular that the provision of ultra wideband signals constitutes <u>intentional</u> jamming of

GPS signals and therefore fails to fall under Part 15. The authorization of ultra wideband is not unintentional, but rather is intentional in every sense of the word. Other commenters have indicated in various testing scenarios that the original ability to lock onto GPS signals is compromised with even the smallest amount of ultra wideband radiation. This is confirmed in the RTCA Special Committee 159 report of March 27, 2001 which constitutes a second interim report to the Department of Transportation and outlines a number of independently developed RFI effects tests on GPS receivers, most notably from Stanford University, Applied Research Labs of the University of Texas, Johns Hopkins University Applied Physics Laboratory, and NTIA GPS RFI Susceptibility Tests and Analysis (See Appendix A).

It is undeniable from every study done so far that the deployment of ultra wideband transmissions will not only materially effect an already locked up GPS receiver to cause erroneous location reporting, it also can result in the failure of the GPS receiver to lock up at all.

No where else would such intentional emission of RF energy in a GPS band be considered anything other than intentional jamming. Thus, the FCC lacks authority under Part 15 to declare that the ultra wideband interference is "unintentional".

III. THE EFFECT OF UWB ON PUBLIC SAFETY

The seriousness of the intentional jamming of GPS signals through the authorization of ultra wideband transmission is nowhere more keenly felt as a threat to public safety. It will be noted that GPS receivers are presently used to locate individuals in distress and to report the position of the individual to a Public Safety Answering Point (PSAP) or like authority. GPS receivers come in essentially two varieties: Autonomous and Assisted. In both cases, the receivers operate on the transmissions from the 26 satellites in the GPS constellation. The signals emitted from the satellites are 40 watt spread spectrum signals, which when they reach the surface of the Earth uncorrelated are at -150 dBm. There are some who consider that the absolute noise floor for the detectability of any electromagnetic signals is -160 dBm. Thus, it can be seen that it is only with extreme difficulty that uncorrelated GPS signals can be received at all.

While systems like ONSTAR and ATX have GPS receivers which are coupled to automotive or vehicle batteries, thus, eliminating the effect of power drain on such a system, for handheld wireless GPS equipped units, power consumption is indeed a factor. As is common practice, the GPS receiver is turned off until such time as a panic button is pressed. The reason is so that the GPS receiver does not drain the wireless phone battery under normal circumstances. Time to first fix for a turned off GPS receiver is critical and dramatically increases in the presence of interference.

It is therefore important that when the situation arises, the satellites be quickly acquired when the GPS receiver and the handset are turned on. It has been found that while the quickest acquisition of GPS signals for a so-called "hot start" is in the 1-3 second range, this quickly deteriorates into 90-120 seconds (or worse) in the presence of interfering radiation. The interfering radiation can be from any of a number of sources and while GPS receivers are designed to eliminate single frequency interference, ultra wideband interference being of a spread spectrum variety is exceedingly difficult to eliminate.

If one were to add even a modicum of additional interfering radiation, public safety would be thwarted in the inability of the GPS receiver to at least initially lock onto the GPS signals.

Further, as shown by the aforementioned report from the RTCA special committee 159, even when the GPS receiver is locked onto the signals and the correlators are functioning, the presence of ultra wideband radiation in fact causes the receivers either to lose lock or to incorrectly report position. Thus, even if there were unlimited battery power to permit the GPS receivers to be on all of the time, positional inaccuracy or loss of lock due to UWB affects public safety adversely.

One of the uses for ultra wideband is in the so-called garage door opener scenario. In this case, it will be appreciated that a transmitter such as a garage door opener may be located no more than a foot, for instance, from a GPS-carrying wireless handset which may be mounted to the dash of the vehicle. Such proximity completely jams GPS receiver and is intolerable from the public safety perspective. Moreover, an even further intolerable situation is when there may be for instance as many as 10,000 radiators in a wireless LAN operation within a short distance. The effect of multiple radiators cannot do anything but deleteriously affect the ability of GPS receivers to lock onto satellites, a major public safety issue.

IV. E-911 REPORT AND ORDER

While the above provides comments with respect to the deleterious effect of a UWB jamming on the public safety sector and E-911 situations, it is very important to note that the UWB authorization would be <u>in direct conflict</u> with the Report and Order (Docket Number 94-102) requiring wireless phones to be located by October 1, 2001. This is because the jamming associated with UWB transmissions would effect not only GPS reception but also the triangulation systems proposed. It will be appreciated that the Report and Order was promulgated to be able to address the problems of the PSAP community. Robustness of solutions to the location problem are of paramount importance to being able to comply with the Report and Order. The Report and Order now permits the utilization of GPS receivers. The Report and Order also contemplates so called triangulation systems which triangulate on the radiation from cell phones. There is however a technological challenge of meeting the present FCC Report and Order as modified which requires triangulation systems to be able to locate a transmitter within 100 meters 67% of the time. The prior standard was 125 meters, and it was only with difficulty that this requirement could be met. The reason is that the apparatus on the cell towers needs to be tuned every 15 minutes for such things as frequency, humidity, wind direction, wind velocity and other second order characteristics to enable these systems to operate appropriately. What will be appreciated is that while GPS is unusually sensitive to low level jamming, so are the triangulation systems and most importantly the tuning which can be affected in the presence of UWB jamming.

V. UWB IS IN CONTRAVENTION OF INTERNATIONAL TREATIES REGULATING THE AMOUNT OF RADIO FREQUENCY INTERFERENCE ACCEPTABLE FOR COMMERCIAL FLIGHT

Additionally, it is the understanding of Tendler Cellular that UWB authorization is in contravention of international treaties regulating the amount of radio frequency interference acceptable for commercial flight. The Department of Transportation is separately filing arguments in support of the notion that UWB should not be authorized due to international regulations as well as practical RF interference problems.

VI. UWB MATERIALLY AFFECTS THE OPERATION OF MILITARY GPS (JAMMING) AND THEREFORE ITS AUTHORIZATION IS A THREAT TO NATIONAL DEFENSE.

Finally, since a UWB authorization materially affects the operation of GPS receivers, ipso facto it affects military GPS receiver as well. The reason is that all present military GPS receivers operate on a so-called CA code which is utilized in order to acquire the signals. Since the publicly available GPS receivers and the military receivers operate on the same principal and are therefore subject to the same deleterious effects of jamming, Tendler Cellular, Inc. is of the opinion that not only will civilian GPS receivers be affected, it is absolutely the case that present military GPS receivers will be likewise affected. As a result, the UWB authorization is a threat to national security and should not be allowed.

CONCLUSION

Tendler Cellular appreciates the opportunity to comment on this obvious matter of importance and wishes to convey to the Federal Communication Commission that at least as far as GPS receivers are concerned, UWB transmissions amounts to intentional jamming of GPS which is so susceptible to low level jamming as noted above. As a result, UWB transmissions are a threat to public safety causing GPS receivers to fail to lock onto the GPS satellites when employed in E-911 situations. Importantly, UWB authorization is in direct conflict with the Report and Order requiring wireless phones to be located by October 1, 2001. UWB authorization is in contravention of international treaties regarding regulating the amount of radio frequency interference acceptable for commercial flight. Finally, UWB transmissions material affect all GPS receivers including military GPS receivers and therefore its authorization is a threat to national security.

Respectfully Submitted,

Robert K. Tendler
Tendler Cellular, Inc.

RTCA Paper No. 086-01/PMC-139

Second Interim Report to the Department of Transportation:

Ultra-Wideband Technology Radio Frequency Interference Effects to Global Positioning System Receivers and Interference Encounter Scenario Development

Prepared by
RTCA Special Committee 159

March 27, 2001

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

The Global Positioning System (GPS) is significant because it is a key element in the development of the "Free Flight" air traffic management structure of the future which is needed to enable the expected growth of air travel and alleviate the currently overcrowded air routes. It is also fast becoming the technology of choice in other public safety positioning and navigation applications (e.g., E-911, maritime, IVHS) and has become imbedded in the national AC power and telecommunications infrastructure. GPS uses, however, a set of rather weak radio signals from satellites in 20,200 kilometer high orbits and, as such, is susceptible to being overpowered by strong terrestrial interference. It operates in one of the "restricted frequency bands" of Title 47 C.F.R. Part 15 and requires protection from harmful interference by international treaty. The FCC in its May 2000 Notice of Purposed Rule Making (on ET Docket 98-153) proposed to allow intentional ultra-wideband (UWB) transmissions across the GPS and several other restricted frequency bands of key importance to aviation and other public safety applications. The proposed power level had previously been allowed only for unintentional spurious emissions.

Since its June, 2000 tasking by the Department of Transportation, RTCA has followed and reviewed 5 major activities relating to UWB radio frequency interference (RFI) to aviation systems, in general, and GPS, in particular. They are the DOT-sponsored UWB RFI tests at Stanford University, The Time Domain Corp.-sponsored RFI data collection effort at Applied Research Labs: University of Texas (ARL:UT), and data analysis effort at Johns Hopkins University Applied Physics Lab (JHU/APL), and two National Telecommunications and Information Administration (NTIA) RFI test and analysis efforts (one on UWB characterization and non-GPS system impact assessment, and the other on GPS RFI impact).

RTCA has also developed RFI encounter scenarios necessary in the impact assessments in particular for aviation precision approach and non-precision approach. RTCA has acted as a forum to help development of other public safety operational scenarios such as cell phone embedded GPS E-911 and maritime navigation in harbors and inland waterways.

Results from the various test programs have been reported and discussed at RTCA. From the Stanford tests on an aviation approach-grade GPS receiver, three different types of UWB RFI effects are observed: CW-like, noise-like, and pulse-like. These are categorized by similarity to previous RTCA published (RTCA/DO-235) susceptibility study results from conventional RFI signals. The degree of UWB RFI impact is observed to depend on UWB signal characteristics such as pulse repetition frequency (PRF), waveform gating and modulation in relation to the GPS receiver bandwidth. Stanford quantified the degree of RFI impact by a "noise equivalency factor" for later use by RTCA in an RFI link analysis.

RTCA developed aviation approach scenarios for Category II/III precision approach and Non-precision approach. The Category II/III scenario was based on previous work for Category I which was recorded in DO-235. From the scenario parameters, an RFI link analysis was performed and yielded the result that maximum allowed UWB RFI emission level must be less than -100 dBW/MHz (28.7 dB below the proposed Part 15 limit of –71.3 dBW/MHz). The non-precision approach case fell within the bounds of the precision approach cases.

NTIA UWB characterization efforts show the usefulness of the RMS spectral density technique in measuring UWB emissions. NTIA non-GPS assessment results showed UWB RFI impact at Part 15 levels to several key Federal systems (up to 6 km spacing required from air route surveillance radars).

Similar to Stanford, NTIA GPS results on a set of general purpose GPS receivers also showed the CW-like, noise-like, pulse-like UWB RFI impacts depending on UWB PRF, waveform gating and modulation in relation to the GPS receiver bandwidth. Susceptibility values were in agreement with RTCA and ITU published standards (-140.5 dBW/MHz broadband, and –150.5 dBW discrete line, relative to a GPS received signal level of –164.5 dBW) even though test criteria were somewhat different than those on which the standards was based. Link analyses for the scenarios used in their compatibility assessments showed UWB low-end power values similar to the RTCA precision approach cases.

JHU/APL concluded from their analysis of the ARL:UT data collection that UWB RFI impact is also waveform-dependent though their results do not bring out the receiver dependence aspect. Furthermore, they concluded that "for UWB devices with average powers that are compliant with the current FCC Part 15 regulations, the performance of GPS receivers exhibits severe degradation when the separation between the GPS receiver and UWB devices is less than about 3 meters." As described in more detail in the body of this RTCA report, RTCA took issue with that conclusion and some related ones. It noted that a device emitting at the Part 15 emission limit in the GPS band 3 meters from a GPS receiving antenna causes the received interference to be more than 200 times the internationally-recognized value for unacceptable interference. This is equivalent to a noise density that is 24.3 dB above the thermal noise density for a typical GPS receiver.

New scenario development work since the first interim RTCA report (Sept. 2000) reported here are initial descriptions of aeronautical mobile satcom safety communications, on-board aircraft personal electronic device RFI to enroute navigation and GPS-based enhanced-911 position reporting through cellular telephone. The E-911 case RFI link analysis shows that indoor GPS-based E-911 is probably one of the most stringent of all the scenarios and requires a UWB power reduction of more than 60 dB below proposed Part 15 limits.

It is clear from the results summarized above and discussed in this report that UWB RFI impact to GPS and other key systems is not negligible as some of its proponents claimed. Due to the complexity of the interaction, considerable care and further work will likely be needed before rules for UWB can be drafted. Since some of the UWB RFI studies are on-going, the RTCA study group will continue to review new study material as it becomes available. Final reports for the original GPS L5 RFI environment study and for the update to the RTCA DO-235 study report on the GPS L1 environment are planned for release early in 2002.

2.0 INTRODUCTION

In October, 1999, at the request of the Department of Transportation (DOT), the RTCA undertook an effort to investigate the radio frequency interference (RFI) environment in the vicinity of the new Global Positioning System (GPS) L5 frequency (1176.45 ± 12 MHz) and determine appropriate receiver susceptibility criteria and related RFI unwanted emission limits for the use with new civil signal. Aviation-related issues were acknowledged to be of primary importance, but the group was encouraged to seek significant involvement and input from non-aviation GPS uses, especially public safety applications (e.g., maritime, E-911, police, fire fighting). By June 2000 the pace had intensified on regulatory and business activities related to ultra-wideband (UWB) transmission technology. As a result the DOT requested the RTCA enlarge the study to explicitly treat UWB RFI effects and operational scenarios for the GPS L1 frequency (1575.42 ± 12 MHz) as well as L5.

Two interim reports were requested on the RTCA study effort. In September, 2000 RTCA Special Committee 159 released its first interim report[1] to the DOT on its study of UWB transmitter RFI testing on GPS receivers and RFI encounter scenario development. That report covered the study activities through early August 2000. Since that time efforts to complete further RFI testing, refine scenarios, and perform RFI link analyses encountered difficulties and delays that forced a 3 month delay in second interim report. To provide policymakers an early update on the aviation-related portion of the continuing RTCA RFI study effort, a preliminary aviation approach segment of the second interim report[2] was released in early February 2001, and covered study progress through the end of January. Among the information on key activities unavailable at that time were the National Telecommunications and Information Administration (NTIA) GPS RFI study results and the Johns Hopkins University Applied Physics Lab (JHU/APL) analysis of the Applied Research Labs: University of Texas (ARL:UT) UWB RFI tests raw data. Some aviation and non-aviation public safety interference scenario descriptions were also unavailable.

The information missing at the end of January has largely been supplied to RTCA by mid March so the full second interim report could be released. This second interim report will cover in Section 3.1 the latest update of the Stanford University/DOT-sponsored RFI test results and include an explanation of the observed UWB discrete spectral line RFI. Section 3.2 contains summaries of the Time Domain Corp.-sponsored ARL:UT UWB RFI data collection and JHU/APL analysis of that data. Section 3.3 on the NTIA UWB characterization and non-GPS system RFI impact assessment is unchanged from the aviation approach segment report. However, Section 3.4 has been added to contain summaries of the newly released NTIA GPS

[1] RTCA SC-159, "Ultra-Wideband Technology Radio Frequency Interference Effects to GPS and Interference Scenario Development, First Interim Report to Department of Transportation," RTCA Paper No. 289-00/PMC-108, 12 September 2000, http://rtca.org/comm/pmcSC159report.PDF, "RTCA First Interim Report"

[2] RTCA SC-159, "Preliminary Aviation Approach Segment for the Second Interim Report to Department of Transportation: Ultra-Wideband Technology Radio Frequency Interference Effects to Global Positioning System Receivers and Interference Encounter Scenario Development," RTCA Paper No. 039-01/PMC-128, 2 February 2001, http://www.rtca.org/comm/reports/UWB%20P-Aviation%20Final%2002%2013%202001.pdf, "RTCA Aviation Approach Segment Report"

RFI reports.[3,4] The aviation precision approach scenarios and RFI link budget in the aviation segment report Section 4.1 remain unchanged. New scenario descriptions have been added in Section 4.2 to discuss potential UWB RFI to aeronautical mobile satellite (route) service and on-board UWB personal electronic device RFI to enroute navigation. Section 4.3 contains a new description of scenarios for Enhanced-911 cell phone position reporting with GPS and an RFI link budget. Appendix B contains corrections for some typographical errors from the preliminary aviation approach segment.

The RTCA study group will continue to incorporate new input material as it becomes available. Final reports for the original GPS L5 RFI environment study and the update to the RTCA DO-235 study report on the GPS L1 environment are planned for release early in 2002.

---

[3] National Telecommunications and Information Administration, U.S. Department of Commerce, NTIA Special Publication 01-45, "Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System Receivers," Feb. 2001, "NTIA 01-45".

[4] National Telecommunications and Information Administration, U.S. Department of Commerce, NTIA Report 01-384, "Measurements to Determine Potential Interference to GPS Receivers from Ultrawideband Transmission Systems," Feb. 2001 "NTIA 01-348"

3.0 UWB RFI EFFECTS TESTS ON GPS RECEIVERS

3.1 Department of Transportation-Sponsored Tests at Stanford University

3.1.1 Noise Equivalency Factor Measurement and Analysis Method

A typical set of measurements from the DoT-Stanford University UWB RFI test program on GPS receivers is illustrated below (Fig. 3.1). The curve labeled "BB Noise Only" plots the baseline GPS receiver pseudorange measurement error standard deviation with broadband noise RFI. As indicated, the total interference input power at the accuracy limit is N_{ACC}.

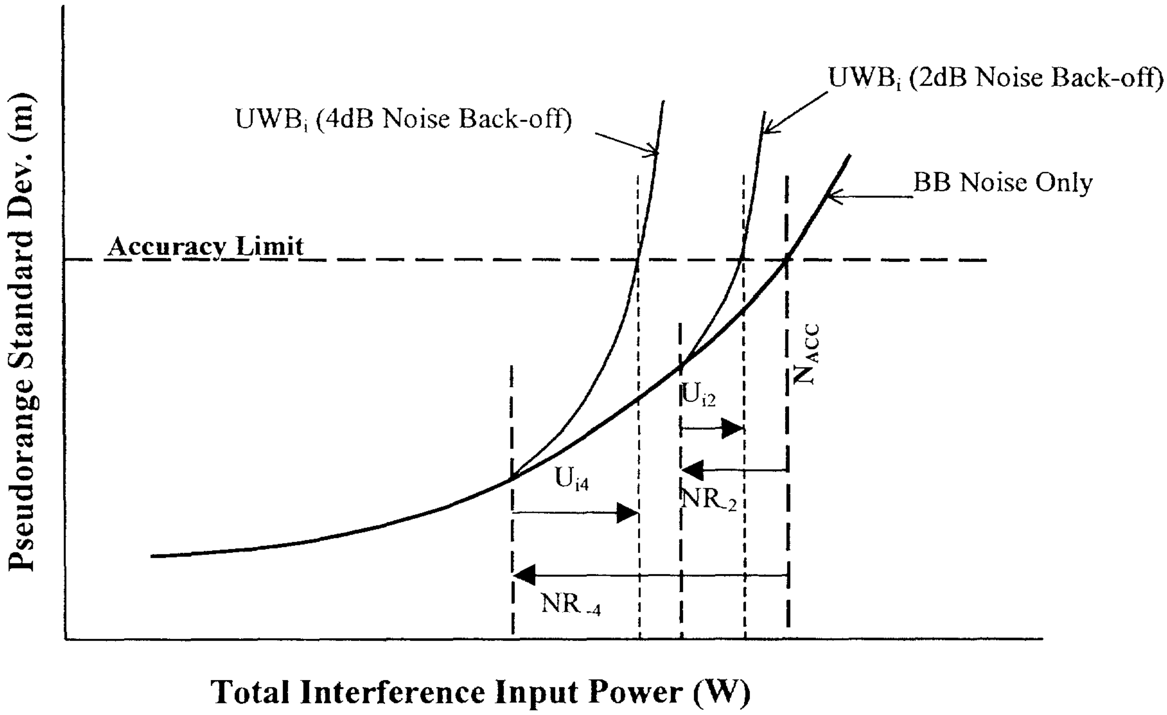

Figure 3.1. Broadband Noise Normalization and Partial UWB Substitution Illustration

The test method calls for making two additional sets of measurements for each UWB interference waveform where UWB RFI power replaces a known portion of the baseline broadband noise power. One set has broadband noise power reduced 4 dB below N_{ACC} (4 dB back-off curve) and the other uses broadband noise 2 dB below N_{ACC} (2 dB back-off curve). From the RFI effects standpoint, the noise equivalency of a UWB waveform comes from a comparison of the UWB power values added back (U_{i4} and U_{i2}) to give the same standard deviation with the known amount of broadband noise power they replaced (NR_{-4} and NR_{-2}). From the example UWB power values U_{i4} and U_{i2} are less than the broadband noise powers, NR_{-4} and NR_{-2}, they replaced to give equal RFI effect. Thus UWB waveform *i* has a greater RFI effect than broadband noise of equivalent power.

A noise equivalency factor numerical value for each UWB waveform is determined as shown in Figure 3.2. First, the values for added UWB power, U_{i4} and U_{i2}, are plotted against the associated broadband noise power removed values, NR_{-4} and NR_{-2}. A "best-fit" straight line is drawn from the origin (the baseline power N_{ACC} corresponds to the zero power reference) through the two UWB power points. The noise equivalency factor is the slope of the best fit line (noise equivalency in dB =10 $\log_{10}$[slope]).

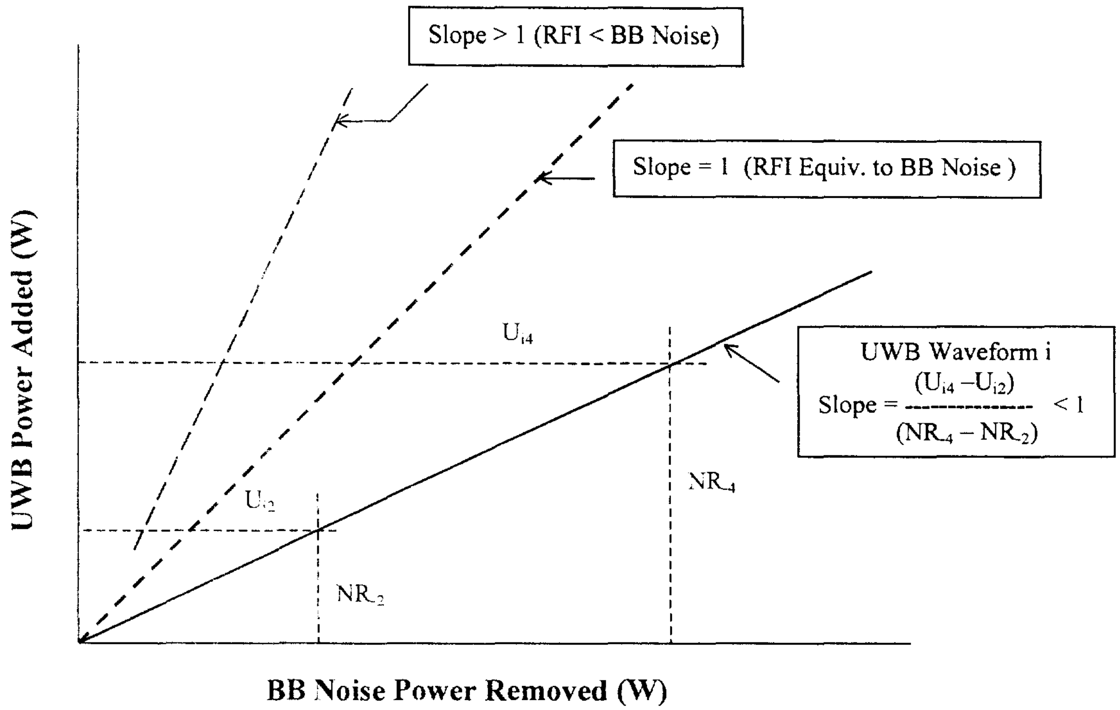

Figure 3.2. Broadband Noise Equivalency Factor Illustration

The curves in Figure 3.2 illustrate three possibilities for the noise equivalency. Namely, a slope less than 1 indicates the waveform has a more harmful RFI effect to GPS than the same amount of broadband noise. A unity slope indicates equivalent RFI effect to broadband noise, while a slope greater than 1 indicates less harmful RFI effect.

Another sort of outcome is also possible. If a line connecting the origin to the two UWB power points shows significant curvature (i.e.; greater than the measurement error for the points), it indicates that the UWB signal is not adding linearly to the noise power. The noise equivalency factor (slope) is still defined but it becomes a function of the amount of broadband RFI present in the particular scenario.

The equivalency factor (in dB) is used in an RFI link budget to correct the allotment for a noise-like RFI signal so the actual UWB emission gives the same RFI effect. That is, once an allocation for a particular amount of noise-like RFI is made to a UWB emitter, the noise equivalency factor (dB) is added to the noise power allotment to give the actual permitted UWB RFI power. If the noise equivalency factor for a particular UWB emitter waveform is –X dB, then the permitted UWB emission level is X dB less than the noise power RFI allotment to UWB.

3.1.2 Stanford University Phase II Test Results

This section contains a summary of the phase II testing of UWB RFI to GPS being conducted at Stanford University under the support of the DoT. A detailed background discussion and the results from phase I testing can be found in Attachment 1 of the October 30, 2000 DoT filing to the Federal Communications Commission (FCC) on the ET Docket 98-153. The first interim RTCA report[5] on UWB RFI also reviewed some of the preliminary results. Phase II testing included aviation receiver pseudorange error data taken for both 2- and 4 dB broadband noise back-off points. In addition, a preliminary investigation into the impact of UWB on GPS signal acquisition has been conducted.

3.1.2.1 Pseudorange Accuracy Testing:

The test configuration is depicted in Figure 3.3 and selected results are included in Figures 3.4, -3.6. Note the pseudorange accuracy threshold in the figures is 1.4 m (partially smoothed).

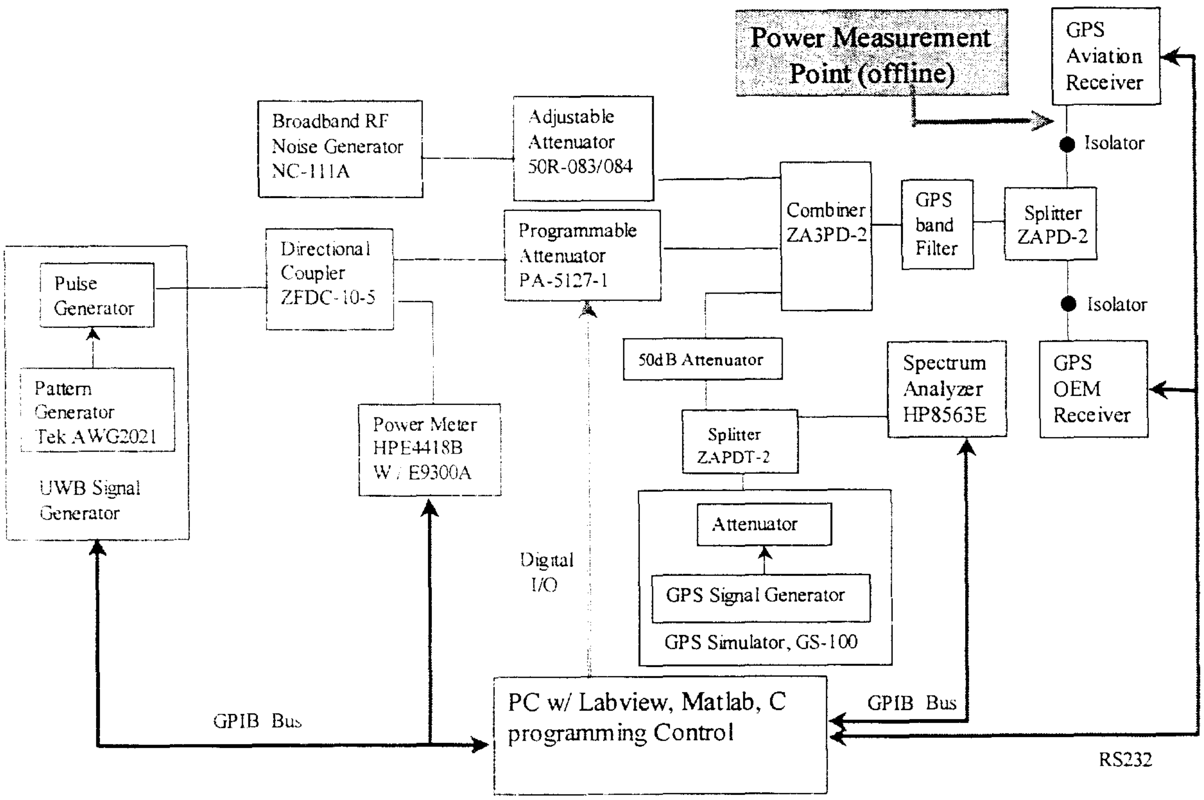

Figure 3.3. Test Set-up for Phase II Testing (Only GPS Aviation Results Reported)

[5] See "RTCA First Interim Report"

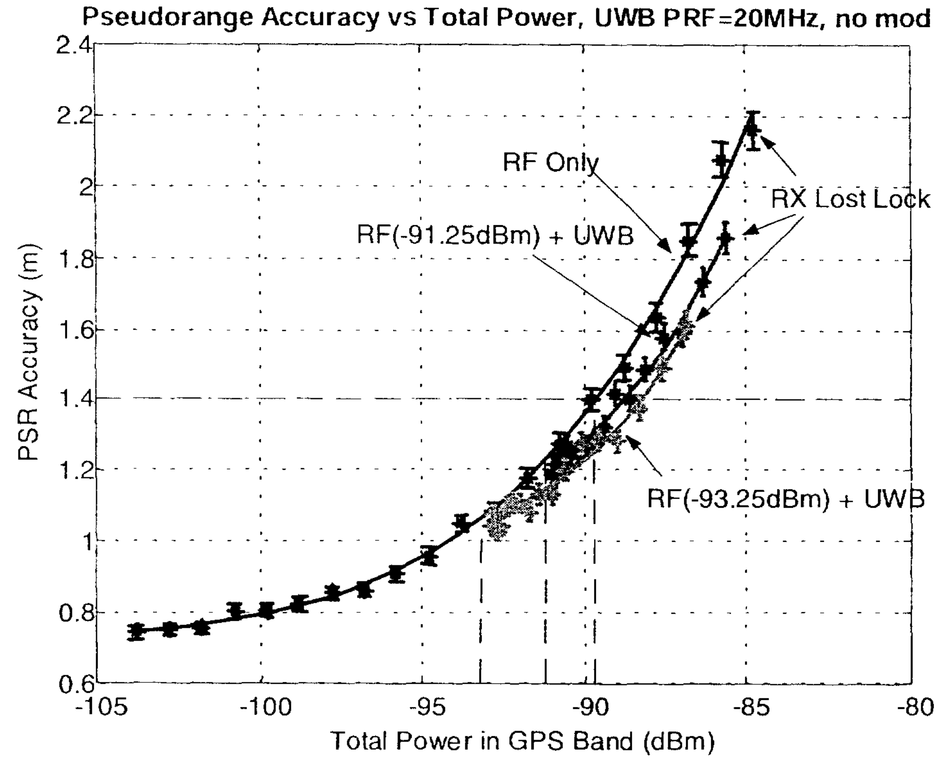

Figure 3.4. Test Results for 2 & 4 dB Back-offs for 20 MHz Constant PRF

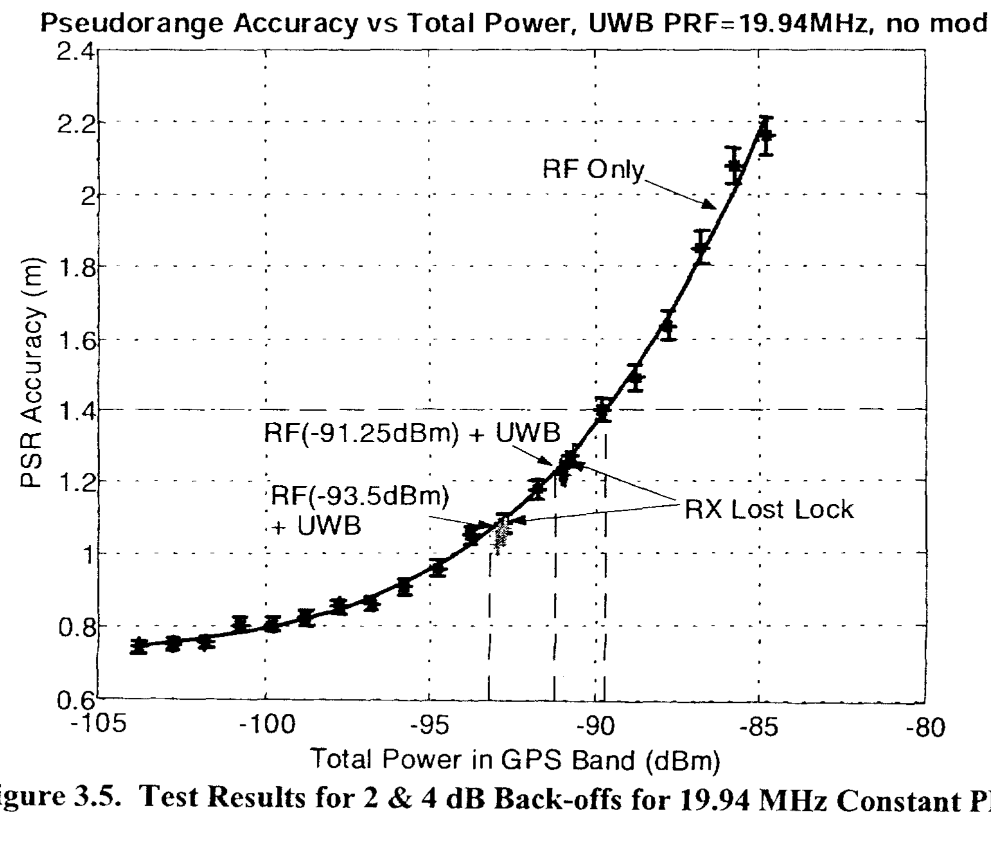

Figure 3.5. Test Results for 2 & 4 dB Back-offs for 19.94 MHz Constant PRF

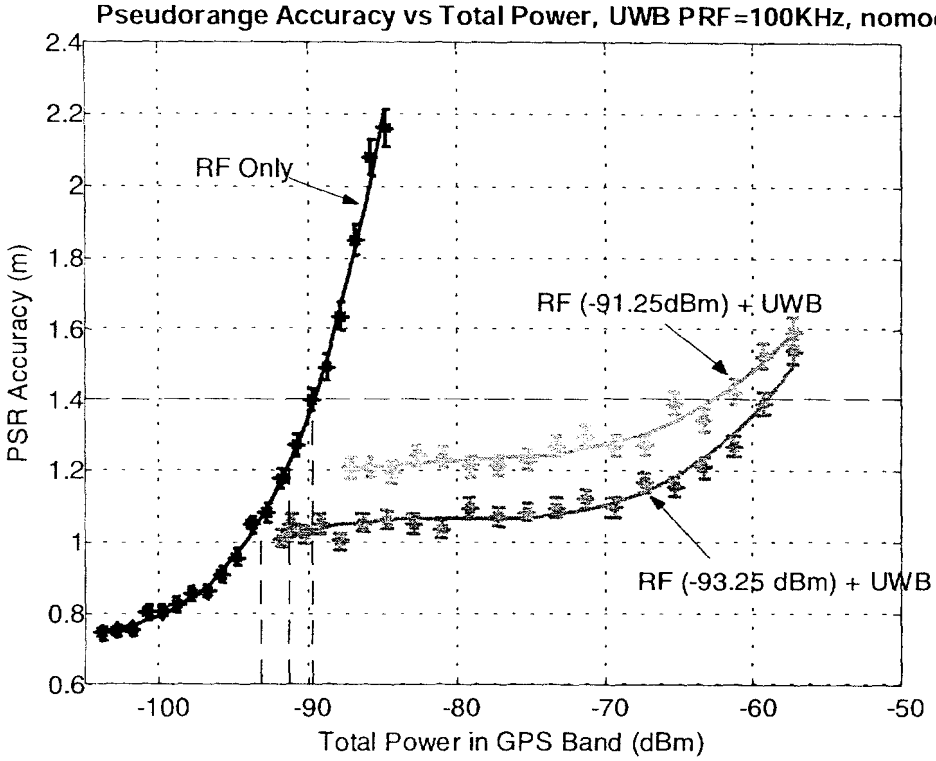

Figure 3.6. Test Results for 2 & 4 dB Back-offs for 100 kHz Constant PRF

In all of the above figures, the curve labeled "RF Only" traces out the pseudorange (PSR) accuracy as a function of broadband noise power in the GPS band. The curve labeled "RF [-93.25 dBm]+UWB" plots the result of the UWB introduction with a 4 dB back-off and the curve labeled "RF [-91.25 dBm]+UWB" is the 2 dB back-off trace.

As discussed in the phase I results, the slight shift in constant pulse repetition frequency (PRF) value from 20.0 MHz to 19.94 MHz introduces a distinct spectral line in the center of the GPS band. That causes a significant problem for the receiver and results in loss-of-lock of the GPS satellite signal with the addition of very little added UWB power. This is shown in Figures 3.4 and 3.5. However, Figure 3.6 shows a different result. For a low PRF, significantly more UWB power, relatively to broadband noise power, can be added for the same impact on accuracy. It is likely that this is a result of the reduced GPS susceptibility to pulsed interference.

For convenience, all testing utilized a GPS power level of –131.3 dBm. The broadband noise power in the GPS band at the 2 dB (or exactly 1.54 dB) and 4 dB (or exactly 3.54 dB) back-off points are –91.25 dBm and –93.25 dBm, respectively. Specific added UWB power levels for the threshold cross points are given in Table 3.1 for the UWB waveforms for which the accuracy degradation threshold was crossed before loss-of-lock. Table 3.2 compares the UWB added power levels at break-lock for selected high RFI impact waveforms with broadband-only break-lock power. Note in the cases listed, the UWB power values with backed-off broadband noise are more than 14 dB below the broadband noise-only break-lock value. The UWB values seem also to be rather insensitive to the amount of broadband noise back-off.

Table 3.1 Accuracy Threshold Levels of Added UWB Power and Removed Broadband Noise Power

Measurement Case		Power level at Pseudo-range error threshold		Noise Equiv Factor (dB)
		dBm	mW	
Noise Power Removed (-2 dB)			3.192e-10	
Noise Power Removed (-4 dB)			5.959e-10	
No mod, PRF=100 kHz	UWB pwr added 2dB Back off	-61.82	6.5763e-7	33.0
	4dB Back off	-59.17	1.2093e-6	
No mod, PRF=20.0 MHz	UWB pwr added 2dB Back off	-92.81	5.2315e-10	5.02
	4dB Back off	-89.82	1.0418e-9	
2P PPM PRF=15.94MHz	UWB pwr added 2dB Back off	-95.64	2.732e-10	-0.5
	4dB Back off	-92.84	5.196e-10	
10P PPM PRF=2.0 MHz	UWB pwr added 2dB Back off	-93.43	4.536e-10	1.16
	4dB Back off	-90.89	8.1465e-10	
10P PPM PRF=1.994MHz	UWB pwr added 2dB Back off	-95.73	2.68e-10	4.5*
	4dB Back off	-89.32	1.1692e-9	

* Average slope - apparent non-linear combination.

Table 3.2 UWB Added Power for Break-lock versus Broadband Noise Break-lock

Measurement Case		Power level at the Rcvr break-lock point	
		dBm	mW
Noise Only		-84.8	3.311e-9
No mod, PRF=19.94 MHz	2dB Back off (N=-91.25dBm)	-102.3	5.9e-11
	4dB Back off (N=-93.25dBm)	-102.3	5.9e-11
2P PPM PRF=15.91 MHz	2dB Back off (N=-91.25dBm)	-99.38	1.15e-10
	4dB Back off (N=-93.25dBm)	-98.38	1.45e-10

The break-lock test results must be translated to account for reference filter bandwidth and interference spectral line frequency before they can be compared with published RTCA receiver narrowband susceptibility and NTIA test results (sec. 3.4). Consider the case of the 19.94 MHz PRF UWB signal. (Fig. 3.5). The firsts step in the translation is to find the power per MHz at the set-up bandpass output for the broadband noise break-lock test. The break-lock noise power value (-84.8 dBm) when divided by the 3 dB bandwidth of the filter (30.5 MHz from Fig. 3.7) results in noise density of –99.64 dBm/MHz. The next step is to adjust downward the total UWB interference power to yield the power in the center frequency line. The two lines at ±19.94 MHz from center are rejected by about 15 dB each so they contribute 6.3 % of the total and the central line 93.7 %. Thus the actual power in the central line is –102.6 dBm (–102.3 – 10*log (0.937)). The ratio of the noise power density value to this corrected CW break-lock power to is -2.94 dB (-102.58 – (-99.64)). The final adjustment is to correct for the actual line frequency involved in the experiment compared to the worst case GPS C/A code line frequency. The following figures (Fig. 3.8 and 3.9) show the worst case lines for PRN 21 (the test satellite) is a ±55 and ±59 kHz from center, while the 19.94 MHz PRF harmonic occurs at –160 KHz from center. The 160 kHz code line height is 6.5 dB lower that the worst case line so the susceptibility is 6.5 dB better. If that adjustment was made in the measured –2.94 dB susceptibility ratio, then the worst case ratio value would be -9.44 dB (in good agreement with the -10 dB value from RTCA standards and NTIA tests).

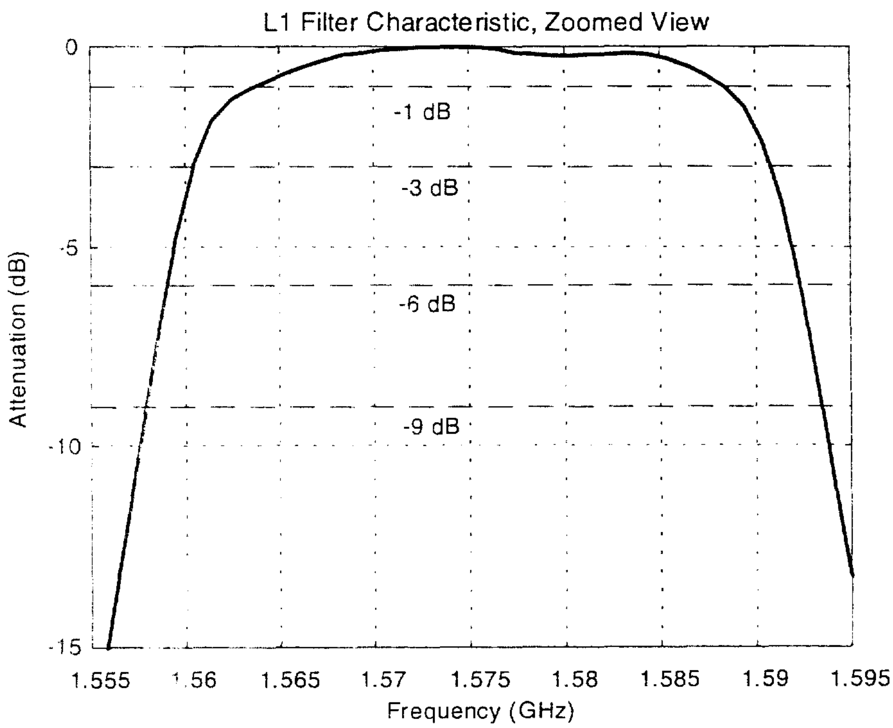

Figure 3.7. Reference Filter Frequency Reponse

1 dB BW: 24.9 MHz, 3 dB BW: 30.5 MHz
6 dB BW: 33.3 MHz, 9 dB BW: 35.6 MHz

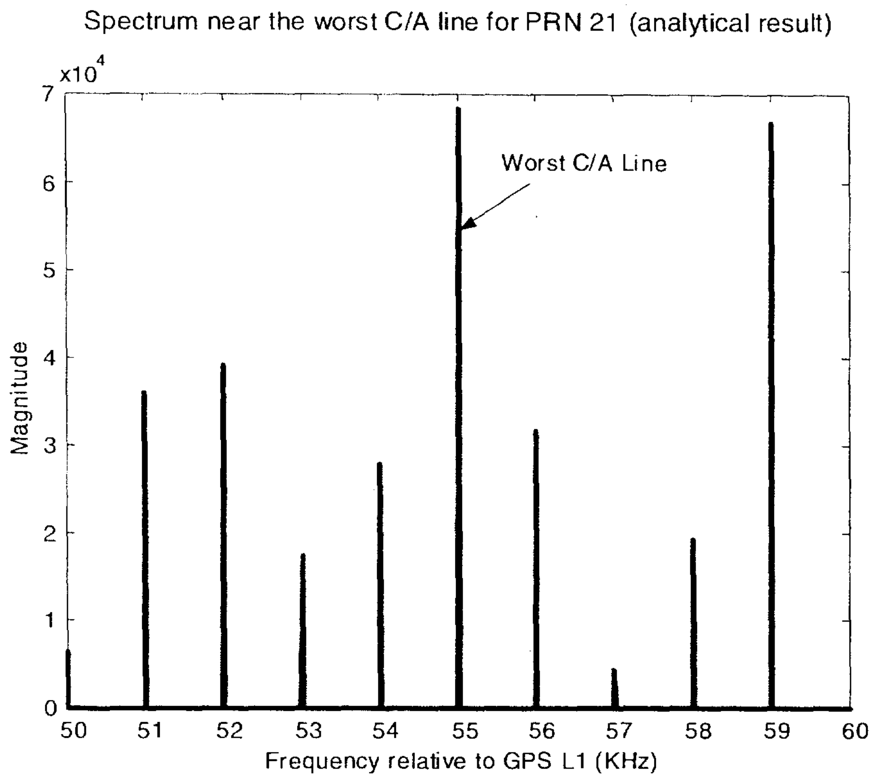

Figure 3.8. PRN 21 Spectrum Around the Most Sensitive Spectral Lines

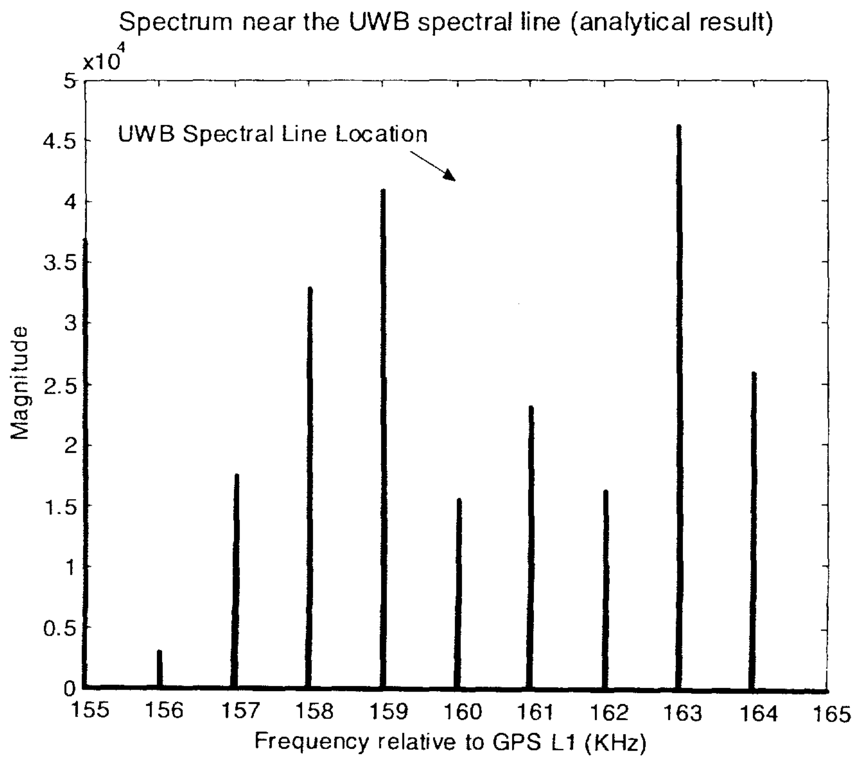

Figure 3.9. PRN 21 Spectrum At the Location of the Result UWB Spectral Line (19.94 MHz PRF)